[0094] According to another aspect of the invention, a method is proposed for designing a tunable and robust laser device of anyone of the mode of realization of the invention, the method comprising at least one of the steps of:

- [0095] adjusting in the range of 2 to 50 the spectral ratio between the Half Width Half Maximum (HWHM) spectral bandwidth of the modal gain and the free spectral range of the optical microcavity and the external cavity, and/or
- [0096] adjusting the ratio between the light power inside the optical microcavity and the light power inside the external cavity in order to be lower than or equal to 1, and/or
- [0097] adjusting the length of the laser optical microcavity so as to meet an anti-resonance condition, and/or
- [0098] designing the external cavity in order to be smaller than or equal to 2 mm.

[0099] The modal gain bandwidth is based on the confinement factor properties on gain layers and material gain properties.

[0100] First the confinement factor can be modified by varying the optical layers properties, as the gain region thickness and/or the top layers properties located before incident medium for example, the incident medium being air for example, and the top layers being a Bragg grating with a predetermined pair number of layers for example. So by varying the microcavity finesse and center wavelength for resonance or anti-resonance conditions, and alternatively the gain layer position relatively to light field antinodes, one can tune both modal gain bandwidth and the ratio of light power inside/outside the gain region.

[0101] Secondly, the material gain bandwidth can be modified by changing for example (i) the atomic composition of the material used in the semiconductor element (semiconductor, doped crystal or fiber . . .) and/or (ii) the excitation density (for semiconductor materials) and/or (iii) the morphology (thickness, geometry like dots, dash, well . . . with semiconductor technologies).

[0102] Also the modal losses filter bandwidth can be adjusted to vary the net modal gain bandwidth (thanks to a metallic absorbing nanometer thick layer on the gain structure and located on or closed to a light field node at center wavelength, an external etalon element, an external fibre based DBR mirror or, output coupler, external volume Bragg grating mirror . . .).

[0103] Typically, the modal gain bandwidth with the microcavity properties can vary from 100 GHz to 10 THz. The material gain bandwidth with semiconductor can vary from 1 THz to 30 THz. Typically, the modal losses bandwidth can be varied from 30 GHz to 10 THz with the different technologies.

[0104] According to one other embodiment, the step of adjusting the ratio between the light power inside the optical microcavity and the light power inside the external cavity may comprise the adjustment of the confinement factor.

[0105] And according to another embodiment, the step of meeting the anti-resonance condition may be obtained by adjusting the total optical length of the microcavity to be an odd number of $\lambda/4$ layers and/or by placing a Bragg mirror onto the exit region to further enhance the light field intensity reduction (antiresonance of the microcavity). The intensity ratio can be varied also by choosing a design wavelength in-between a resonant and an antiresonant wavelength condition.

DESCRIPTION OF THE DRAWINGS

[0106] The methods according to embodiments of the present invention may be better understood with reference to the drawings, which are given for illustrative purposes only and are not meant to be limiting. Other aspects, goals and advantages of the invention shall be apparent from the descriptions given hereunder.

[0107] FIG. **1** shows a schematic view of the laser assembly,

[0108] FIG. **2** shows a schematic view of the mechanical concept of the optical cavity control,

[0109] FIG. **3** shows a schematic view of the semiconductor element according to a first mode of realization, in the form of a graph with the elements represented in function of their band gap energy,

[0110] FIG. **4** shows the reflectivity or the gain spectrum in percents, in function of the wavelength, obtained with the semiconductor element of FIG. **3**,

[0111] FIG. **5** shows a detailed view of the gain spectrum of FIG. **4** around the laser frequency,

[0112] FIG. **6** shows the modes of the external cavity and the gain spectrum,

[0113] FIG. **7** shows the reflectivity (in percent) as a function the incident angle (in degrees) at a pump wavelength of 808 nm of the resonant structure with typical gain/absorption in the active region, for TM or TE polarized pump beams,

[0114] FIG. **8** shows an example of Relative Intensity Noise (dB/Hz) at quantum limit (pump RIN<−160dB) as a function of radio frequency (Hz) of a 10 mm long resonant VECSEL emitting 100 mW at 1 μm,

[0115] FIG. **9** shows an example of Frequency Noise Spectral density (Hz^2/Hz) at quantum limit as a function of radio frequency (Hz) of a 10 mm long resonant VECSEL emitting 100 mW at 1 μm,

[0116] FIG. **10** shows a schematic view of the semiconductor element according to a second mode of realization in an enhanced anti-resonant microcavity configuration, in the form of a graph with the elements represented in function of their band gap energy,

[0117] FIG. **11** shows the reflectivity or the gain spectrum in percents, in function of the wavelength, obtained with the semiconductor element of FIG. **10**,

[0118] FIG. **12** shows a detailed view of the gain spectrum of FIG. **11** around the laser frequency,

[0119] FIG. **13** shows an example of Relative Intensity Noise (dB/Hz) at quantum limit (pump RIN<−152dB) as a function of radio frequency (Hz) of a 0.3 mm long anti-resonant VECSEL emitting 5 mW at 2.3 μm,

[0120] FIG. **14** shows an example of Frequency Noise Spectral density (Hz^2/Hz) at quantum limit as a function of radio frequency (Hz) of a 0.3 mm long anti-resonant VECSEL emitting 5 mW at 2.3 μm,

[0121] FIG. **15** shows a simple antiresonant design of the device according to a mode of realization of the invention and without the use of top Bragg mirror,

[0122] FIG. **16** shows the ratio between the light power inside the gain structure and through the external cavity as a function of wavelength for the antiresonant, for the design illustrated in FIG. **15**,

[0123] FIG. **17** shows the electric field density across such a design,